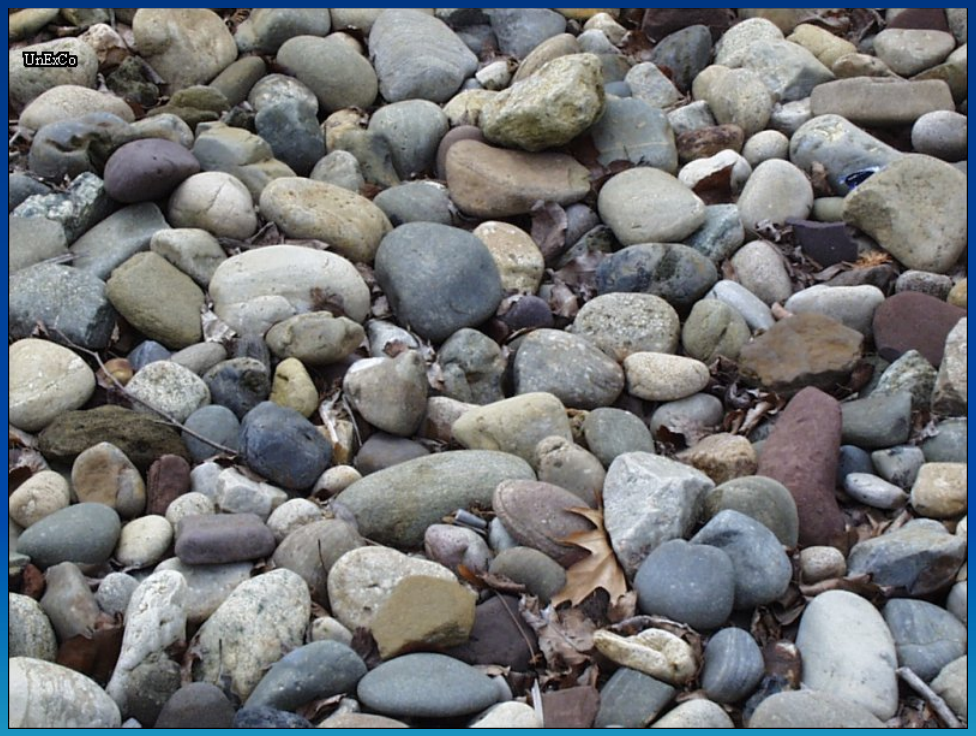
Honors Earth Science: Rocks

Rocks

- Rocks are made from minerals!!!



Three Types

- Igneous
- Sedimentary
- Metamorphic
- Classified by how they form
- All connected by the Rock Cycle (Earth is a system!)

Igneous Rocks

- "Formed by Fire"
- Formed as hot molten magma or lava cools and crystallizes
- Magma contains gases like water vapor
- Magma also consists of elements found in the silicate minerals
  - Silicon, oxygen, aluminum, iron, calcium, sodium, potassium, magnesium, and others

Igneous Rocks Continued…

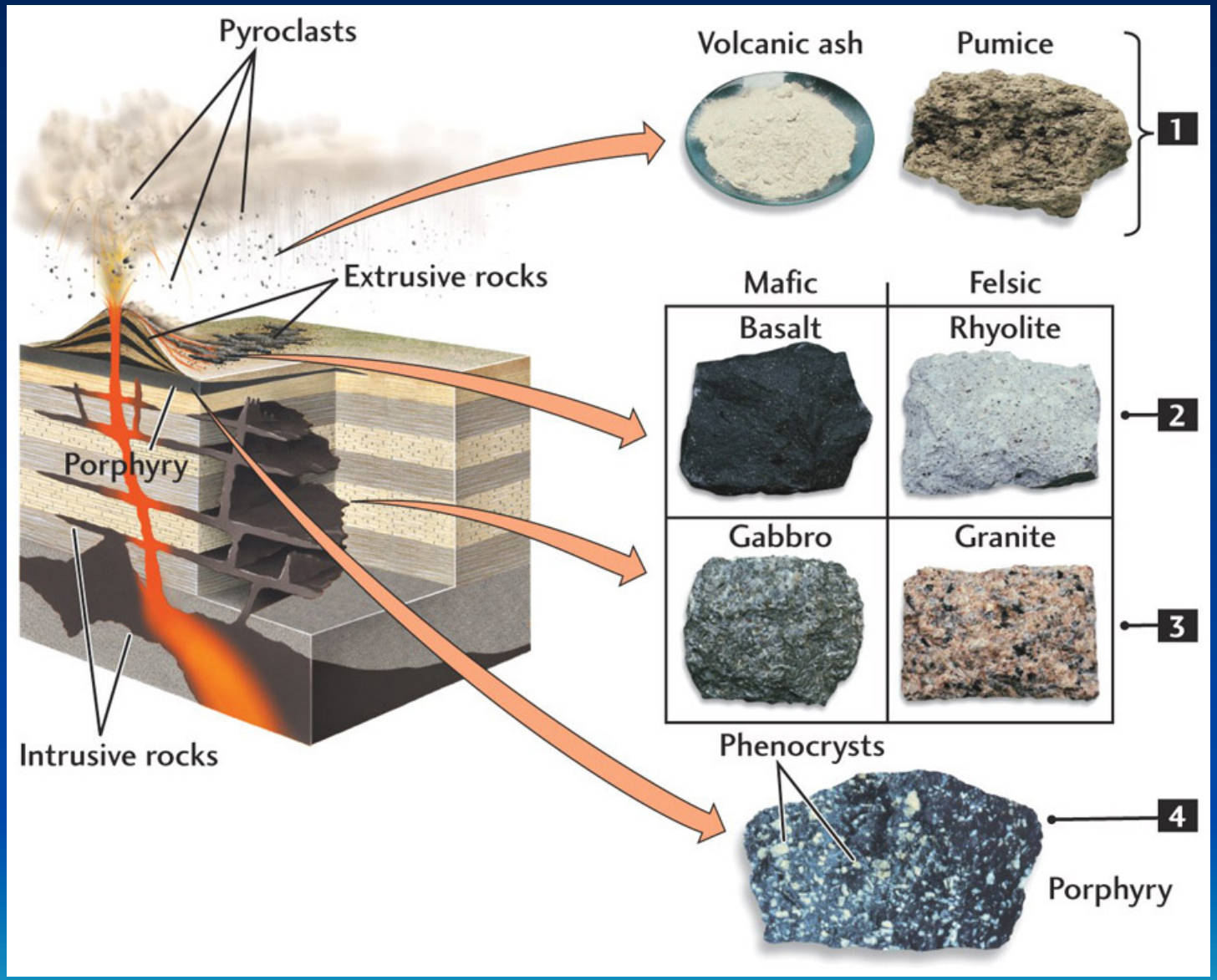
- Magma is less dense than the surrounding rock so it eventually makes its way to the surface
- Lava---magma that reaches the Earth's surface; most of the gases have escaped

Two Types

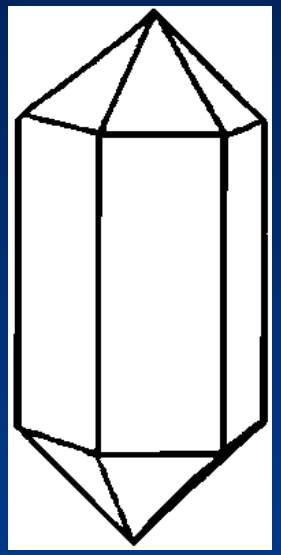
- Intrusive
  - Igneous rocks made from crystallization of magma (intrude existing rock)
  - Also called plutonic (named for Pluto, Roman god of the underworld)
- Extrusive
  - Igneous rocks made from solidification of lava (extrude onto the surface)
  - Also called volcanic (named for Vulcan, Roman god of the fire and forge)

Two Types

- Intrusive
  - Coarse grained
  - Cool slowly
  - Most common is granite
- Extrusive
  - Fine grained or glassy
  - Cool quickly
  - Sometimes they are **vesicular** with tiny holes formed by the release of trapped gases
  - Most common is basalt


Pyroclasts
Volcanic ash
Pumice
1
Extrusive rocks
Mafic
Felsic
Basalt
Rhyolite
2
Porphyry
Gabbro
Granite
3
Intrusive rocks
Phenocrysts
4
Porphyry

Crystallization



- Crystallization influenced by
  - Rate of cooling
  - Composition of magma
  - Amount of dissolved gases
- As magma cools, ions arrange themselves into orderly patterns
- Does not occur at same time
- Rate of cooling influences crystal size
  - Slow cooling → Large crystals
  - Rapid cooling → Small crystals
  - Instant quenching → Glass

Classifying Igneous Rocks

- Based on two things
  - Texture
  - Mineral Constituents
- Texture
  - Overall appearance of an igneous rock based on size, shape, and arrangement of its crystals

Texture

- Glassy: instantaneous cooling (ex-obsidian)
- Aphanatic: fine grains (ex-basalt)
- Phaneritic: coarse grains (ex-granite)
- Pegmatic: very large crystals
- ** Porphyritic: mixture of different crystal sizes (caused by complex cooling)
- Vesicular: contains tiny holes due to gas bubbles in the magma or lava

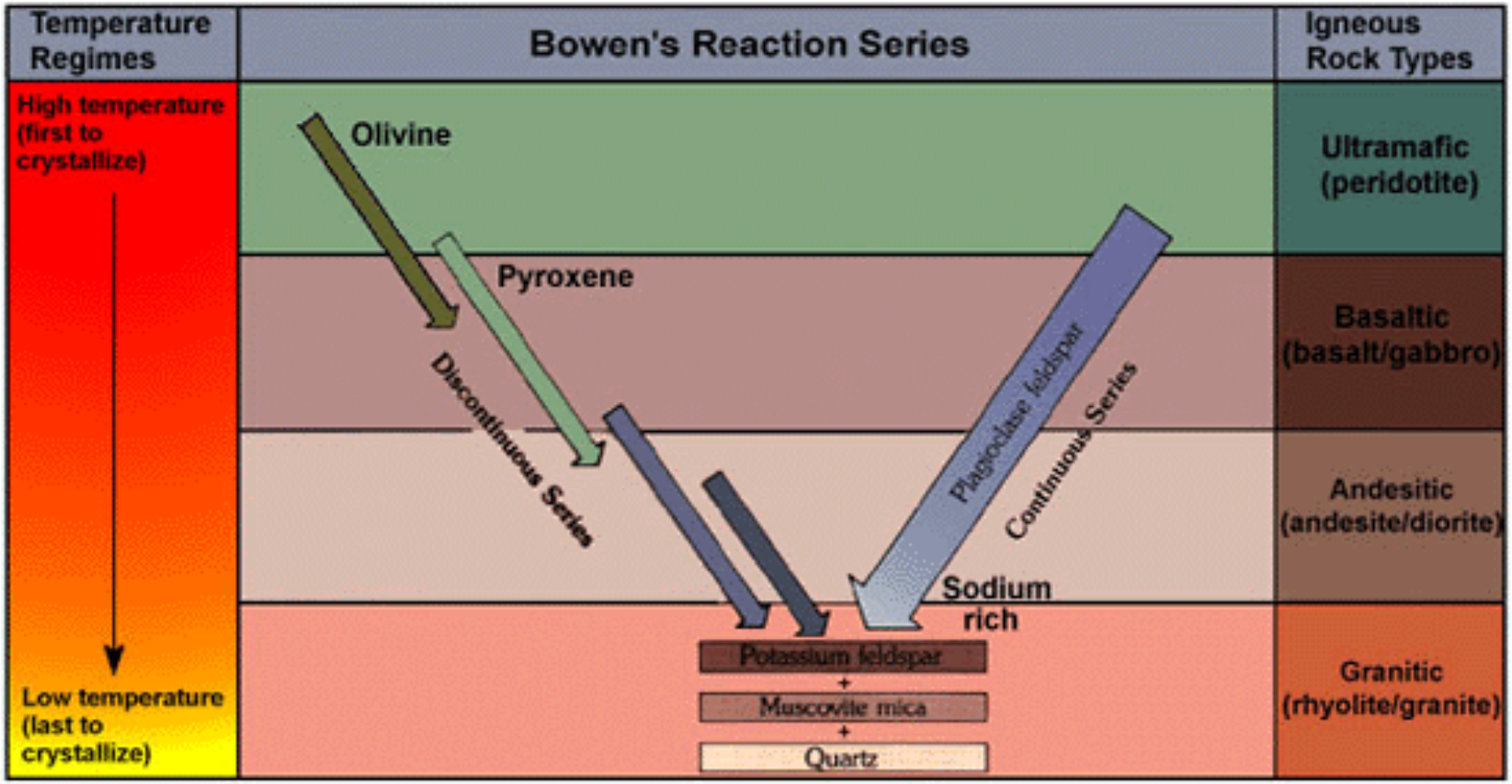
Obsidian (glassy)

Mineral Composition

- Mineral make-up of rock depends on chemical composition of magma
- Single magma might produce rocks of varying mineral content because various eruptive stages of the same volcano often extrude lavas exhibiting different mineral compositions
- Studied by N. L. Bowen

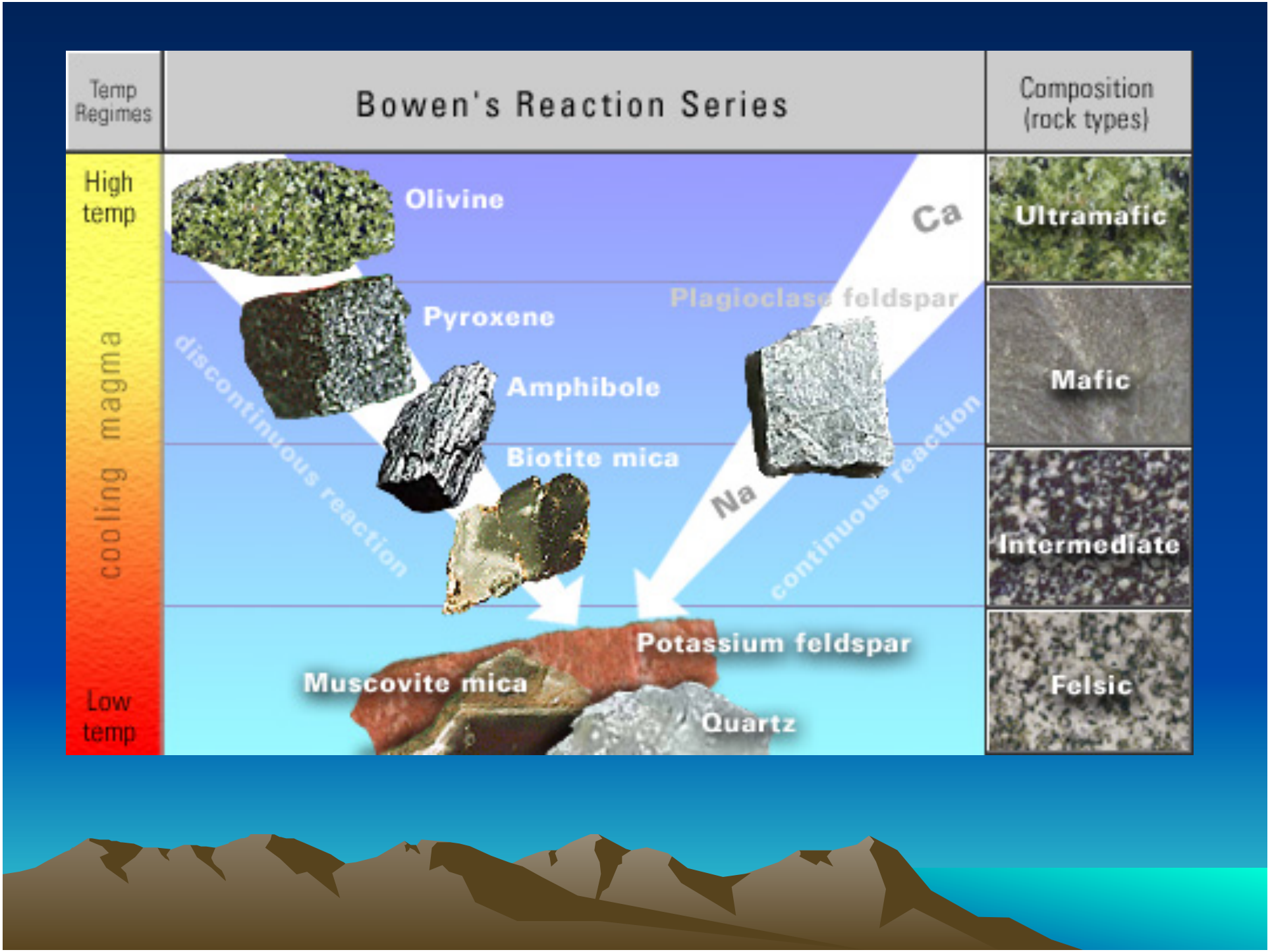
Bowen's Reaction Series

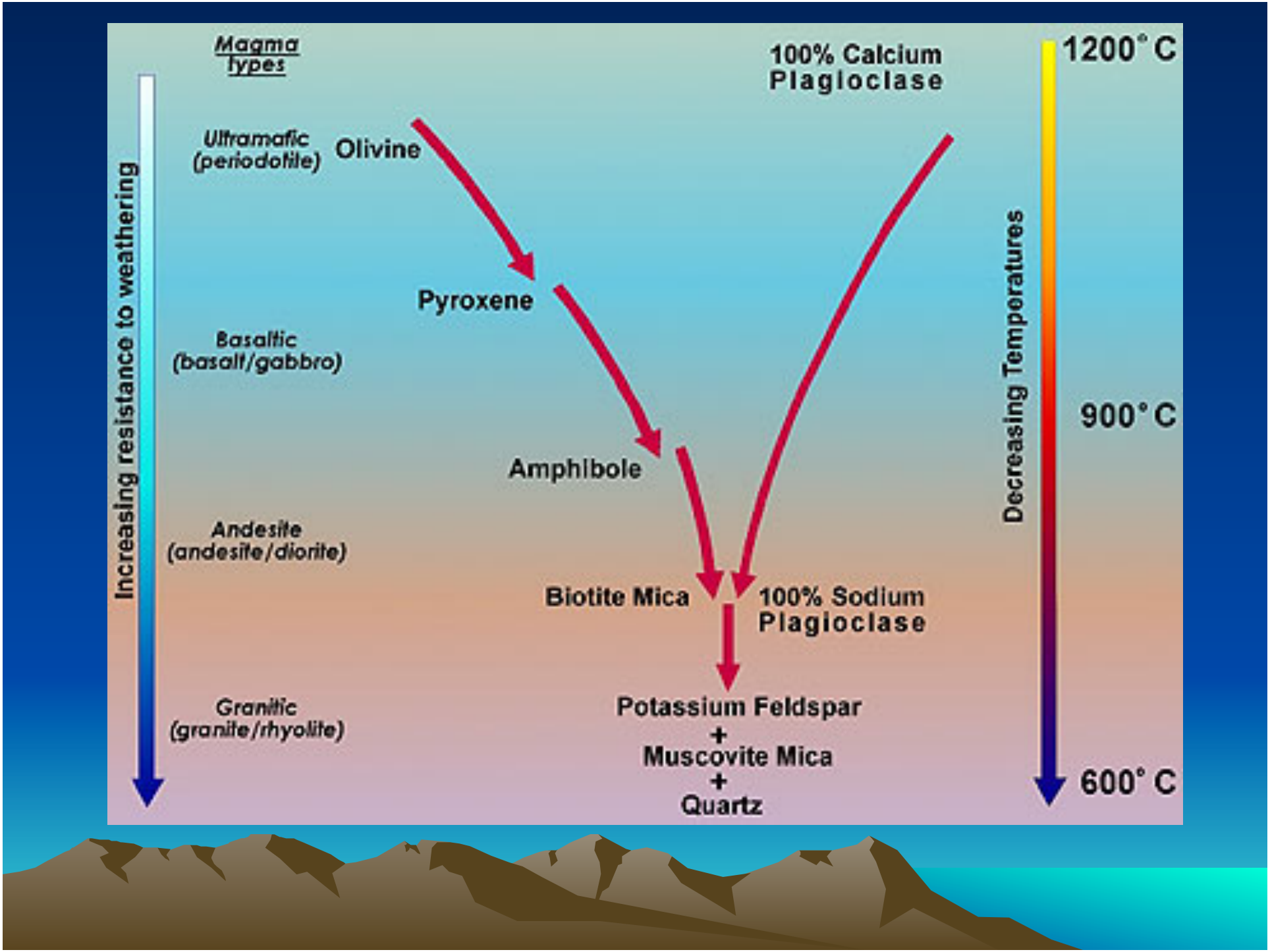
- Discovered as magma cools, certain minerals crystallize first at very high temperatures and others crystallize at lower temperatures
- If a mineral remains in the molten solution after crystallization, it will react with the remaining liquid to produce the next mineral in the sequence



Bowen's reaction series.

7


Temp Regimes
Bowen's Reaction Series
Composition (rock types)
High temp
cooling magma
Low temp
Olivine
Pyroxene
Amphibole
Biotite mica
Potassium feldspar
Muscovite mica
Quartz
Ca
Na
Plagioclase feldspar
discontinuous reaction
continuous reaction
Ultramafic
Mafic
Intermediate
Felsic


Magma types
Ultramafic (periodotite)
Olivine
Pyroxene
Basaltic (basalt/gabbro)
Amphibole
Andesite (andesite/diorite)
Biotite Mica
100% Calcium Plagioclase
100% Sodium Plagioclase
Granitic (granite/rhyolite)
Potassium Feldspar + Muscovite Mica + Quartz
Increasing resistance to weathering
Decreasing Temperatures
1200° C
900° C
600° C

Bowen's Reaction Series

- Read about this series in your text
- Minerals that form at about the same temperature are found together in the same igneous rock
- Crystal settling-earlier formed minerals are denser than the liquid portion and settle to the bottom
- Separation of solid and liquid components at various stages of crystallization produce a wide variety of rocks

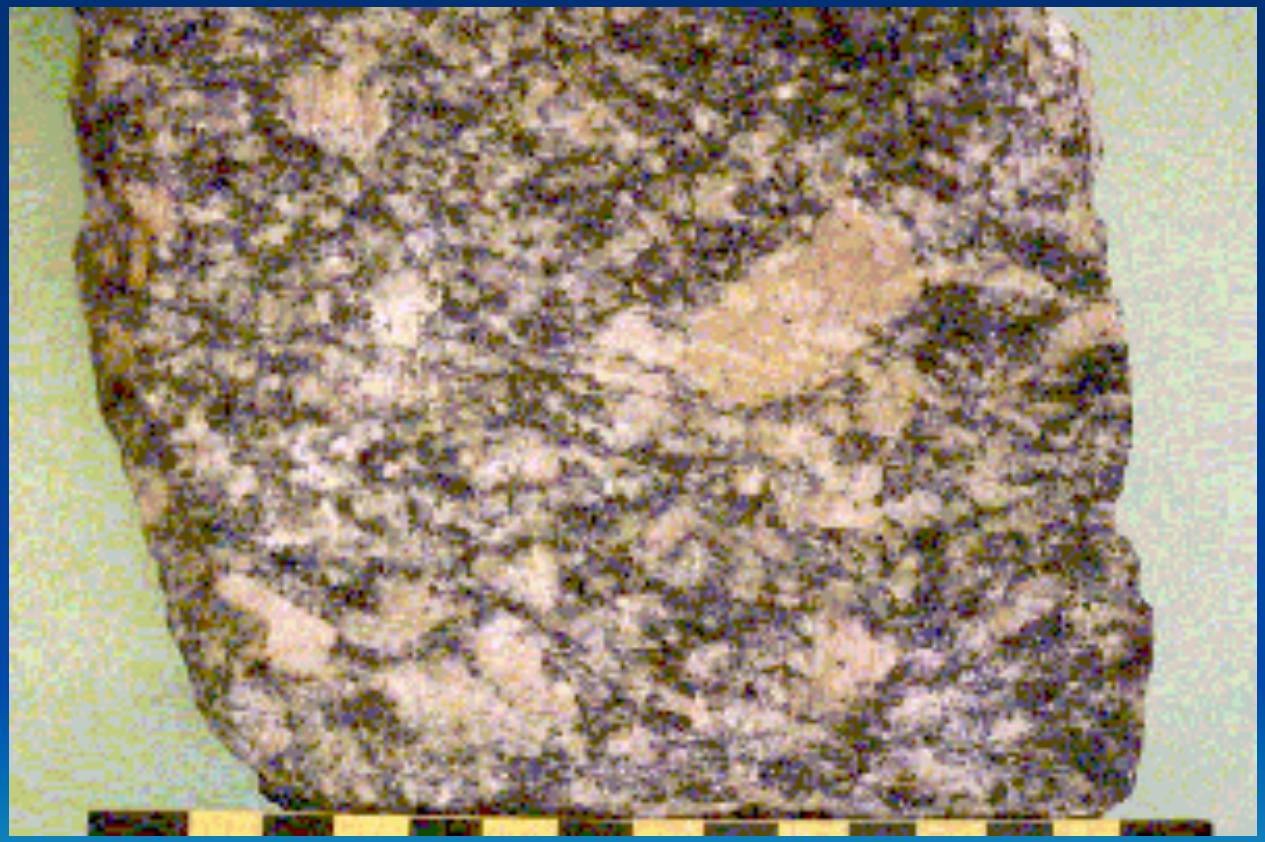
Grouping Igneous Rocks

- Grouped according to their texture and mineral composition
  - Felsic
  - Mafic
  - Ultramafic
  - Andesitic (not in text)

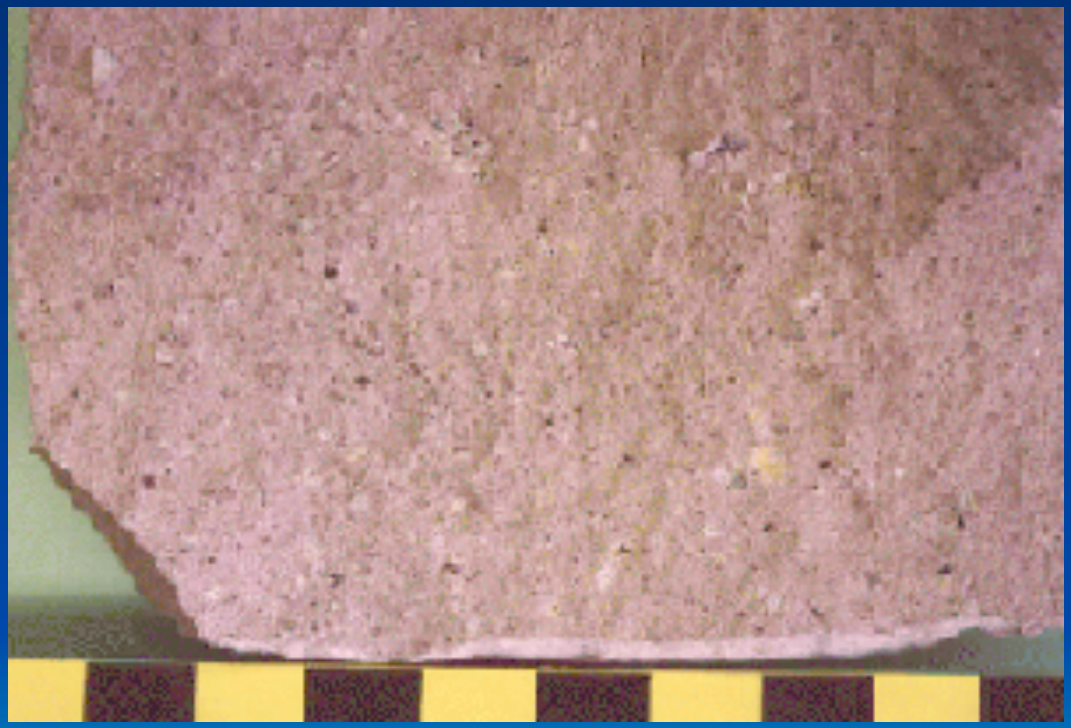
Felsic

- Term comes from feldspar and silica
- Also called granitic rocks
- Light-colored
- High silica content (70%)
- Contain quartz and feldspar
- Part of continental crust
- Examples: granite (best known) and rhyolite (read about them in text)
- Uses: tombstones, monuments, and building stones

Granite (porphyritic)



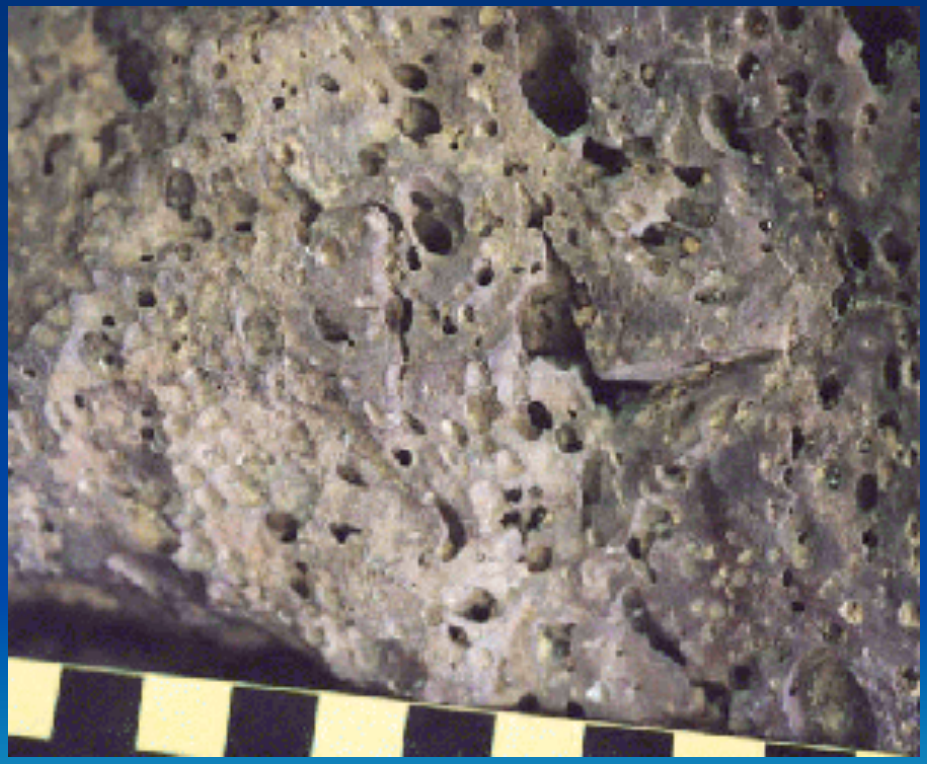
Rhyolite (aphanatic)



Mafic

- Term from magnesium and ferrum or iron
- Also called basaltic rocks
- Dark-colored and dense
- Lower silica content (50%)
- Contain minerals feldspar, biotite, amphibolite, pyroxene, and olivine
- Rich in iron and magnesium
- Part of oceanic crust and volcanic islands
- Examples: basalt (most common) (read about in text), gabbro

Basalt (vesicular)



Ultramafic

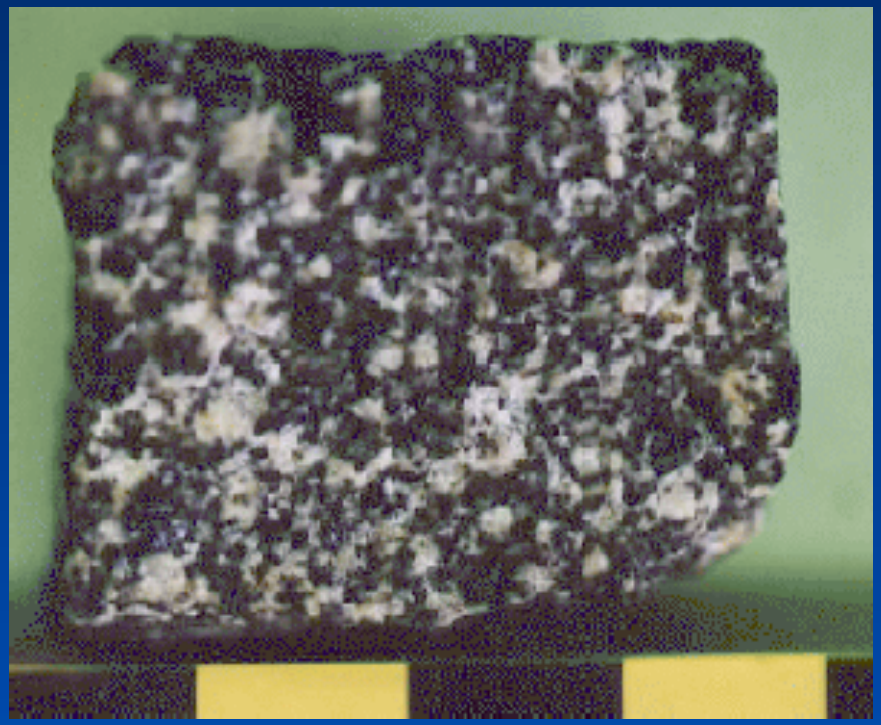
- Almost all iron and magnesium
- Low silica
- Mostly minerals pyroxene and olivine
- Rare at Earth's surface
- Examples: peridotite (main component of upper mantle), dunite

Peridotite

Andesitic

- Also known as intermediate
- Composition in between felsic and malfic
- Associated with volcanic activity at the edges of continents
- Examples: Andesite, diorite

Andesite

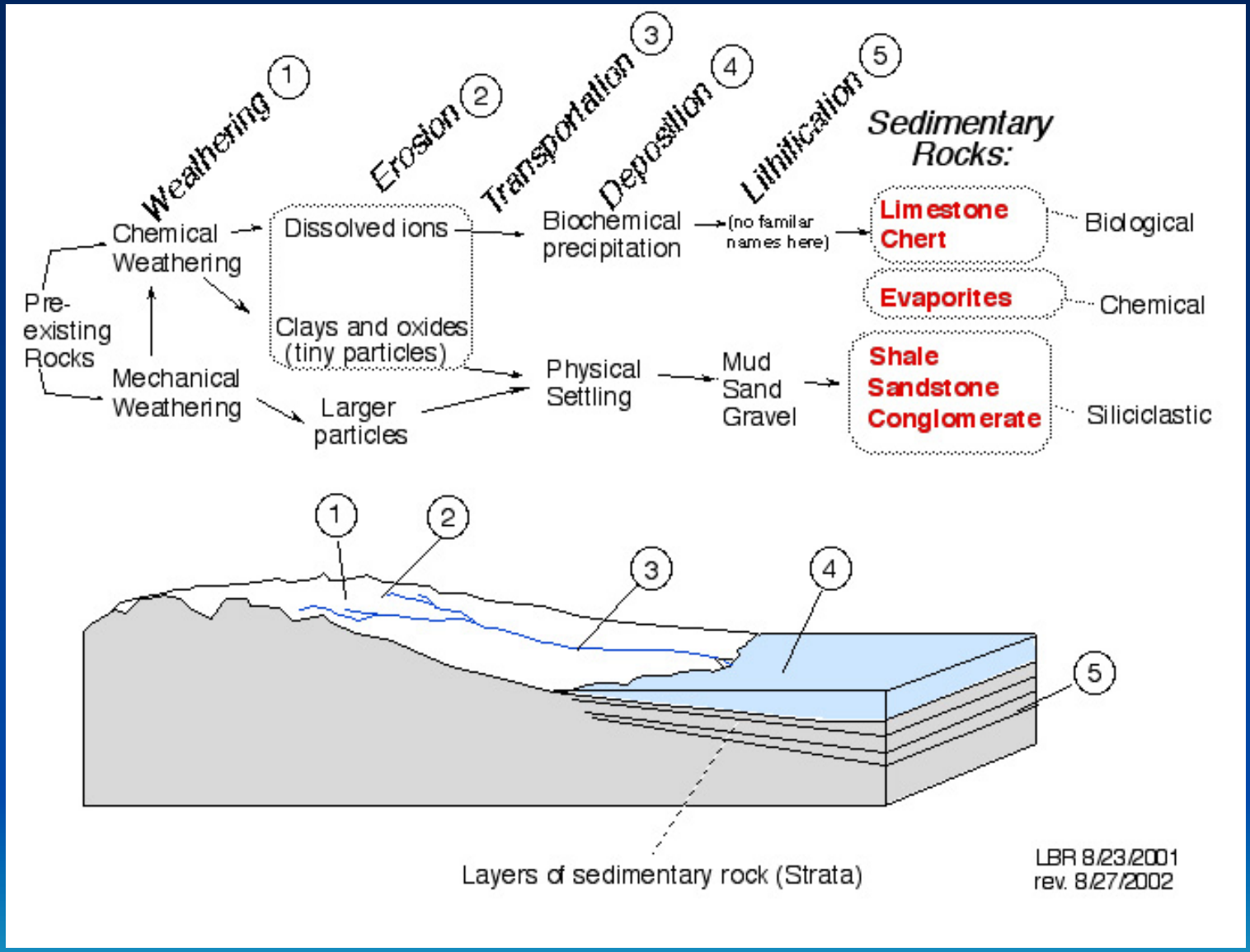


Sedimentary Rocks

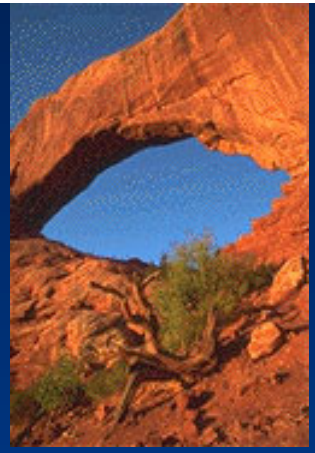
- **Sediment**---loose particulate material (clay, sand, gravel, etc.); pieces of solid material that have been deposited on Earth's surface by wind, water, ice, gravity, or chemical precipitation
- When sediments become cemented together, they become sedimentary rocks

Formed by Four Processes

- Weathering
- Erosion and Deposition
- Compaction
- Cementation


Weathering 1
Erosion 2
Transportation 3
Deposition 4
Lithification 5
Sedimentary Rocks:
Pre-existing Rocks
Chemical Weathering
Mechanical Weathering
Dissolved ions
Clays and oxides (tiny particles)
Larger particles
Biochemical precipitation
(no familar names here)
Physical Settling
Mud
Sand
Gravel
Limestone
Chert
Biological
Evaporites
Chemical
Shale
Sandstone
Conglomerate
Siliciclastic
1
2
3
4
5
Layers of sedimentary rock (Strata)
LBR 8/23/2001
rev. 8/27/2002

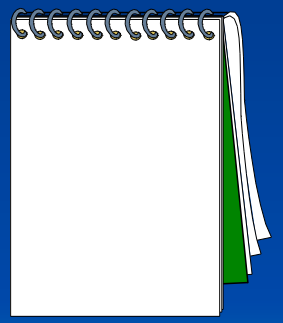
Weathering



- The wearing away of rock
- Physical and chemical processes that break down rock into small pieces
- Mechanical weathering: physical forces break rock into smaller and smaller pieces without changing the mineral composition
- Chemical weathering:chemical transformation of rock into one or more new compounds

Weathering Examples

- Chemical
  - Example: burning a piece of paper
- Mechanical
  - Example: tearing a piece of paper



Mechanical Weathering

- Frost wedging
  - Repeated cycles of freezing and thawing of water
  - Water expands when it freezes (9%) so it expands and enlarges cracks and voids in rocks → causes rocks to break into pieces
- Expansion resulting from unloading
  - Igneous rock is exposed by erosion and breaks loose into layers (sheeting) →caused by reduction in pressure
  - Outer layers expand and separate and cause exfoliation domes
  - See Figure 3.4

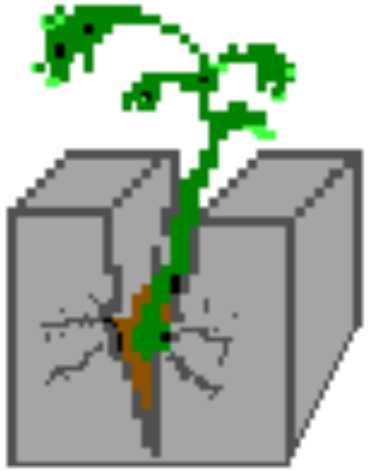
Mechanical Weathering

- Biological Activity
  - Plant roots, burrowing animals, and humans

Mechanical Weathering Includes:

Unloading

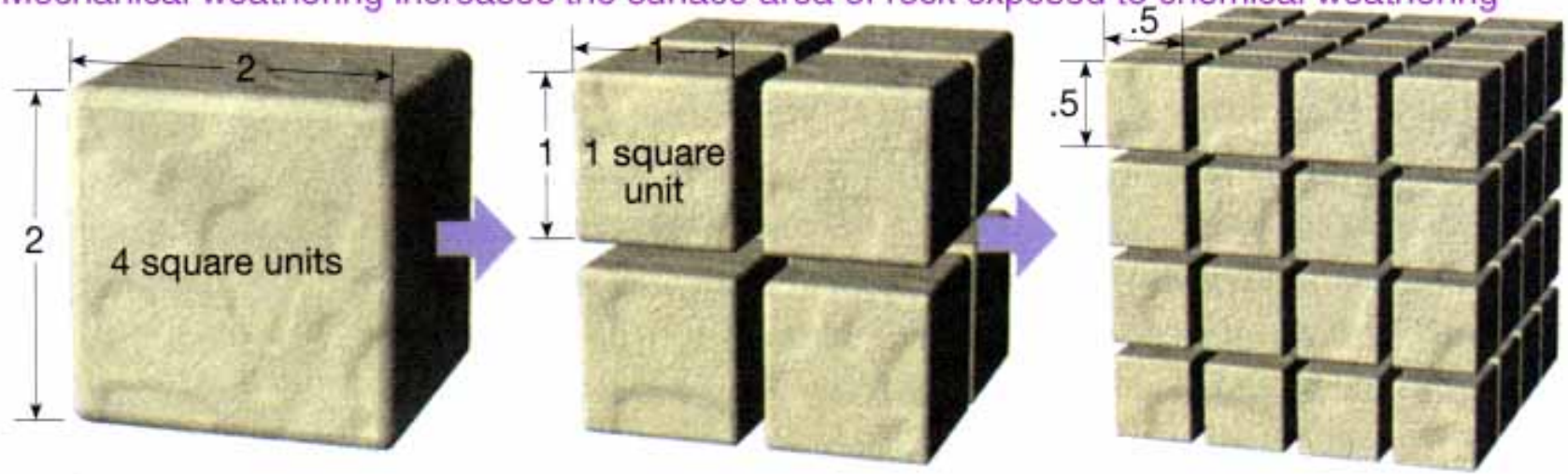
Frost Action



Root Wedging

Temperature Change

Mechanical weathering increases the surface area of rock exposed to chemical weathering



4 square units ×
6 sides ×
1 cube =
24 square units

1 square unit ×
6 sides ×
8 cubes =
48 square units

.25 square unit ×
6 sides ×
64 cubes =
96 square units

Exfoliation Dome

Chemical Weathering

- Water and Carbonic Acid
  - Oxygen dissolved in water oxides minerals
  - Think of the hematite we looked at (rust)
  - Carbonic acid forms as rain dissolves carbon dioxide as it falls
  - Read about this on pg. 71-72

Rates of Weathering

- Dependent upon rock characteristics and climate
  - Mineral composition
  - Solubility
  - Joints/cracks in the rocks (water penetrates)
  - Marble weathers faster than granite (headstones)


FATHER
WM WALTERS
DEC. 24, 1838
OCT. 18, 1888

Rates of Weathering Continued

- Silicates weather in the same order as their order of crystallization (see Bowen's Reaction Series)
  - Olivine crystallizes first and is least resistant to chemical weathering
  - Quartz crystallizes last and is most resistant
- Warm temperatures and abundant moisture climates speed up chemical weathering
- Differential weathering---rocks do not weather uniformly

Differential Weathering

Erosion and Deposition

- The removal and movement of surface materials from one location to another
- Four agents of erosion
  - Wind, moving water, gravity, and glaciers
  - Materials are almost always moved downwards

Erosion and Deposition Continued…

- Deposition---when sediments are laid down on the ground or sink to the bottoms of bodies of water
- Occurs when transport stops
- Forms layers with largest grains at bottom and smallest grains at top
- Largest particles settle out first

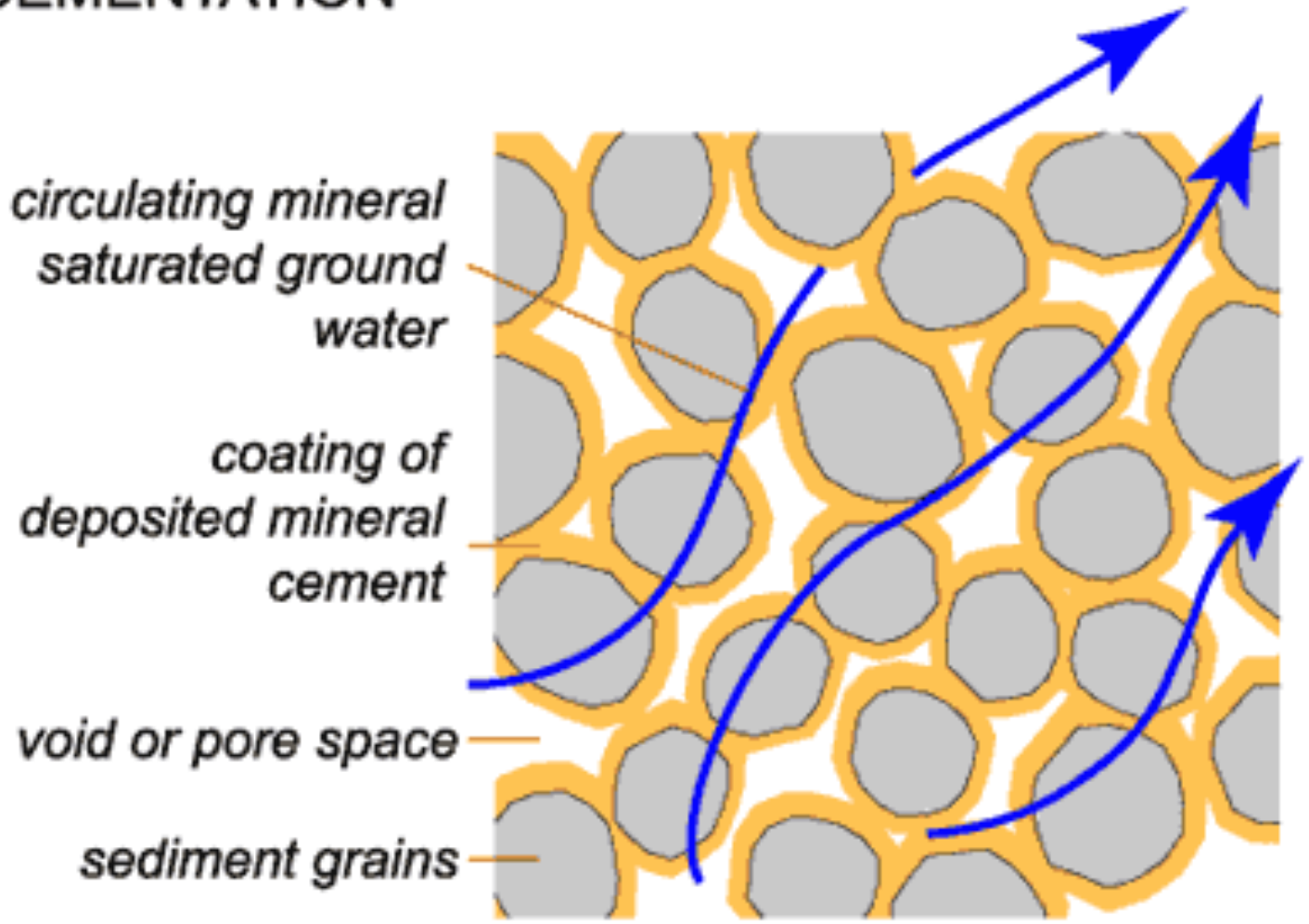
Lithification

- Physical and chemical processes that transform sediments into sedimentary rock
- Includes compaction and cementation
- Compaction---the weight of the overlying sediments forces the sediment grains closer together (physical change)
- Cementation---mineral growth cements sediment grains together into solid rock

Cementation

- Two ways:
  - New minerals (like calcite) grows between grains
  - Same mineral grows between and over grains (called overgrowth)
  - Most common cements are calcite, silica, and iron oxide

CEMENTATION



Sedimentary Rocks

- Accounts for 75% of all rock outcrops on the continents (surface)
- Only account for 5% of Earth's outer 16 kilometers
- Tells us about Earth's history (rock layers and fossils)
- Important economically (power from coal) (sources of iron, aluminum, sand, gravel, etc.) (petroleum and natural gas occur within pores)

Classifying Sedimentary Rocks

- Two categories
  - Detrital
    - Sediments originate as solid particles from weathered rock
  - Chemical
    - Sediments originate as soluble material produced by chemical weathering

Detrital

- Contains abundance of clay and quartz
- Clay produced by weathering of silicates (feldspar)
- Four size categories
  - Coarse-grained or gravel sized (ex: conglomerate: sediment is rounded and breccia: sediment is angular)
  - Medium-grained or sand sized (ex: sandstone)
  - Fine-grained (ex: siltstone)
  - Very-fine-grained (ex: shale: most common sed rock)

Conglomerate

Breccia

Sandstone

- Has high porosity
- Porosity: percentage of open spaces between grains in a rock
- Fluids may move through it

Shale

Siltstone

Chemical

- Formed from precipitation of dissolved minerals in water
- Remember supersaturated solutions???
- Chemical rocks distinguished by their mineral composition
- Common: salt left behind after seas evaporate or skeletons left behind when organisms die

Minerals Precipitate from Water

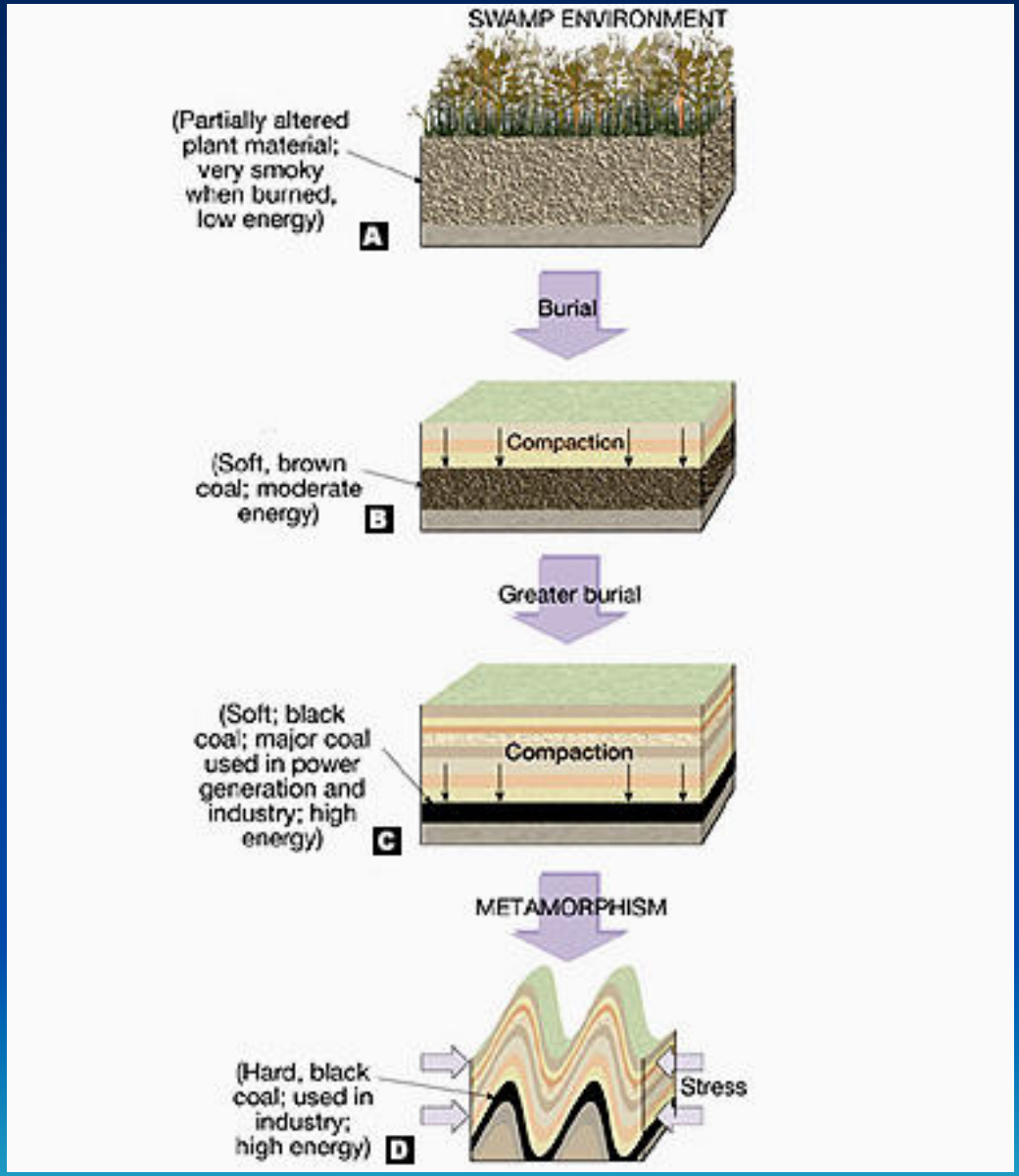
- Commonly called evaporites
- Most common evaporite minerals are calcite, halite (rock salt), and gypsum
- Commercial importance
  - Salt
  - Gypsum: Plaster of Paris, drywall, and plaster

Limestone

- Most abundant example of sedimentary rock is limestone (composed of calcite)—made from skeletons and shells of ocean organisms and coral

Coal

- Another example is coal---made from remains of plant material
- Lignite and bituminous coals are sedimentary rocks, but anthracite is metamorphic


SWAMP ENVIRONMENT
(Partially altered plant material; very smoky when burned, low energy)
A
Burial
Compaction
(Soft, brown coal; moderate energy)
B
Greater burial
(Soft; black coal; major coal used in power generation and industry; high energy)
Compaction
C
METAMORPHISM
(Hard, black coal; used in industry; high energy)
D
Stress

Metamorphic Rocks

- Metamorphism means "changed form".
- Changes occur because of:
  - Heat
  - Pressure
- Occurs at great depths
- Metamorphic rock forms when high temperatures and pressure combine to alter the texture, mineralogy, or chemical composition of a rock

Changes Caused

- Increased density
- Growth of larger crystals
- Foliation (banding)
- Transformation of low-temp minerals into high-temp minerals

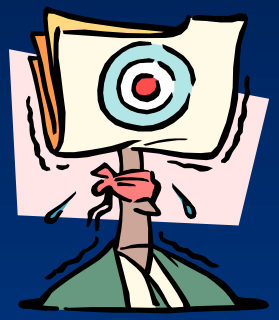
Metamorphism

- During metamorphism, the rocks must remain essentially solid
- Low-grade metamorphism
  - Slight changes
  - Shale to slate
- High-grade metamorphism
  - Substantial changes

Metamorphism

- Two settings
  - Contact or thermal
    - Rock is intruded by a magma body
    - Change is driven by a rise in temperature
  - Regional
    - Occurs during mountain building
    - Rock directed to high pressures and temperatures

Agents



- Heat
  - Comes from magma rising from below and rocks experiencing increase in temperature as they are transported to greater depths
- Pressure
  - Increases with depth as the thickness of the overlying rock increases
  - Confining pressure: forces are applied in all directions
  - Produces more compact rock having greater density
  - Differential stress: forces that generate mountains and are unequal (produces elongated rocks---forms texture)

Agents Continued

- Chemically active fluids
  - Water and other volatiles, including carbon dioxide
  - Act as catalysts to promote recrystallization

Textures

- 2 Types
  - Foliated
  - Nonfoliated

Foliated

- **Foliated** is a broad term referring to the alignment of sheet-like minerals (such as the micas, muscovite and biotite).
- Produces wavy layers or bands
- See Figure 2.22
- Examples:
  1. **Slate** (comes from shale)
  2. Phyllite (comes from slate)
  3. **Schist** (comes from phyllite)
  4. **Gneiss** (comes from granite or schist)

Gneiss

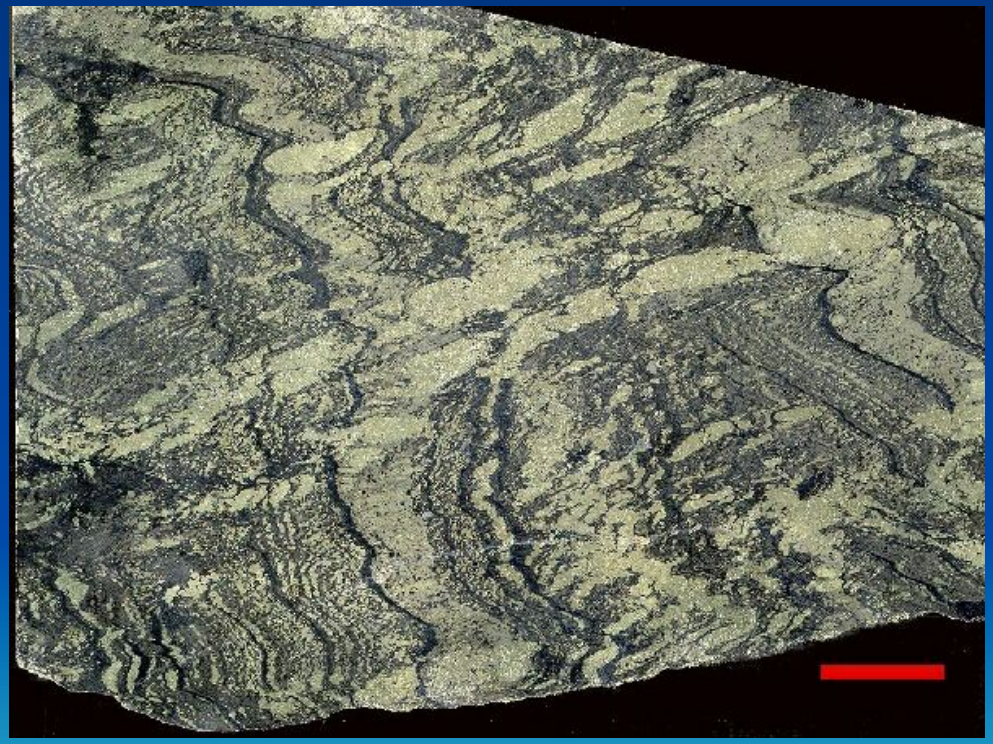
- Read about on pg. 60

Slate

- Read about on pg. 59

Schist

- Read about on pg. 59



Nonfoliated

- **Non-foliated** or **granular** metamorphic rocks are those which are composed of equidimensional grains (such as quartz or calcite). The grains form a mosaic.
- Lack waves or bands
- Examples:
  - Quartzite (comes from sandstone)
  - Marble (comes from limestone)
  - Anthracite coal (comes from bituminous coal)

Quartzite

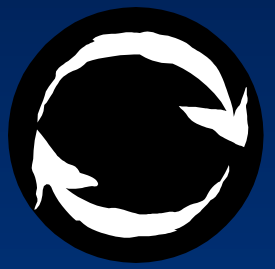
- Read about on pg. 60

Marble

- Read about on pg. 60

Anthracite

Rock Cycle



- Helps us to understand the origins of the three types of rocks
- Helps us to see how each type is linked to the others by the processes that act upon and within the planet
- The basic cycle
  - Magma → Igneous → Sedimentary → Metamorphic → Magma → and around and around

Rock Cycle Continued

- Alternative Paths
  - Any type can become any other type at any time
- Any path takes a very long time to occur
- Read about the paths in your text

The Rock Cycle

Sedimentary Rocks undergo tremendous heat and pressure and form Metamorphic Rocks.

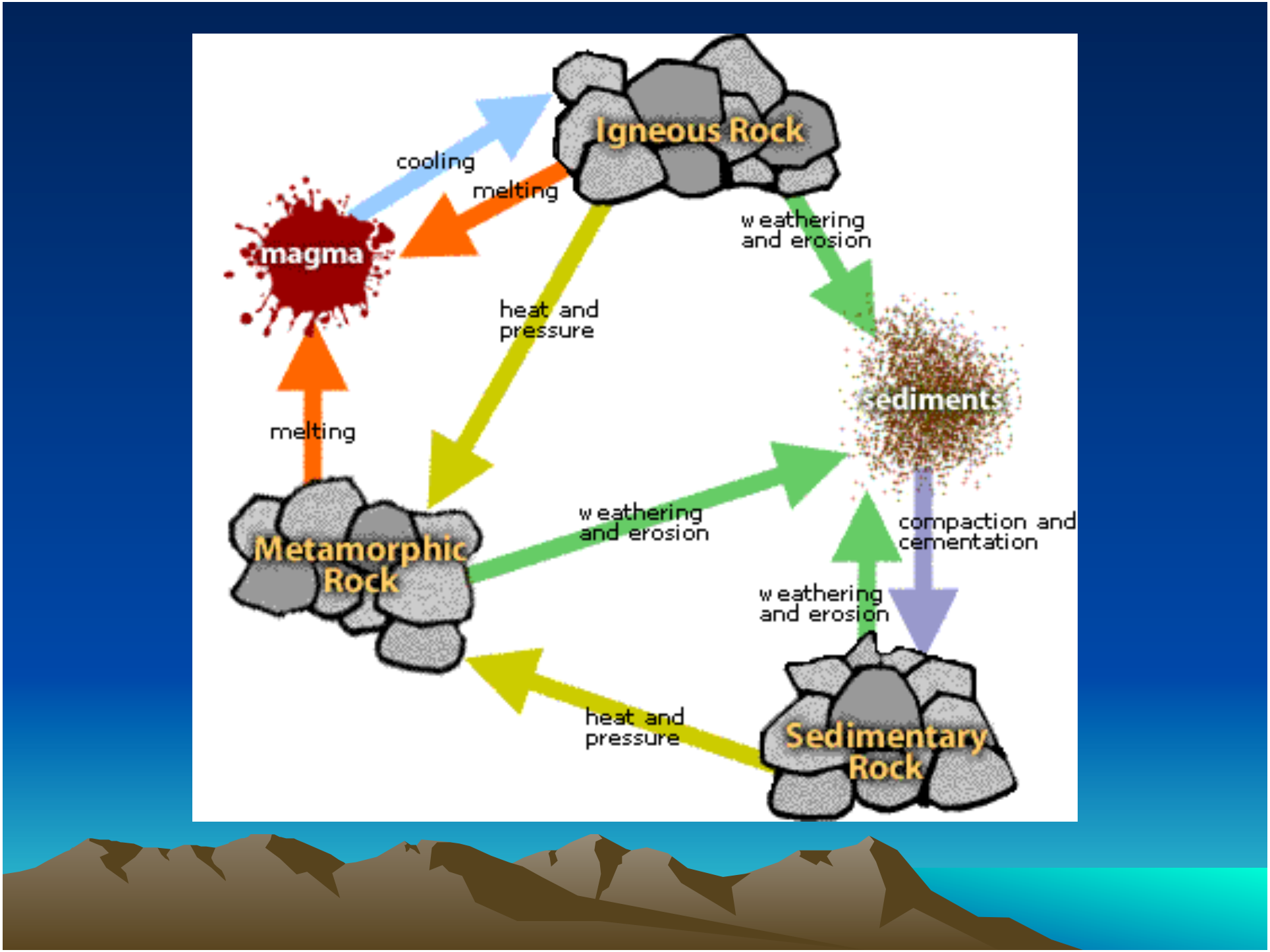
Metamorphic Rocks

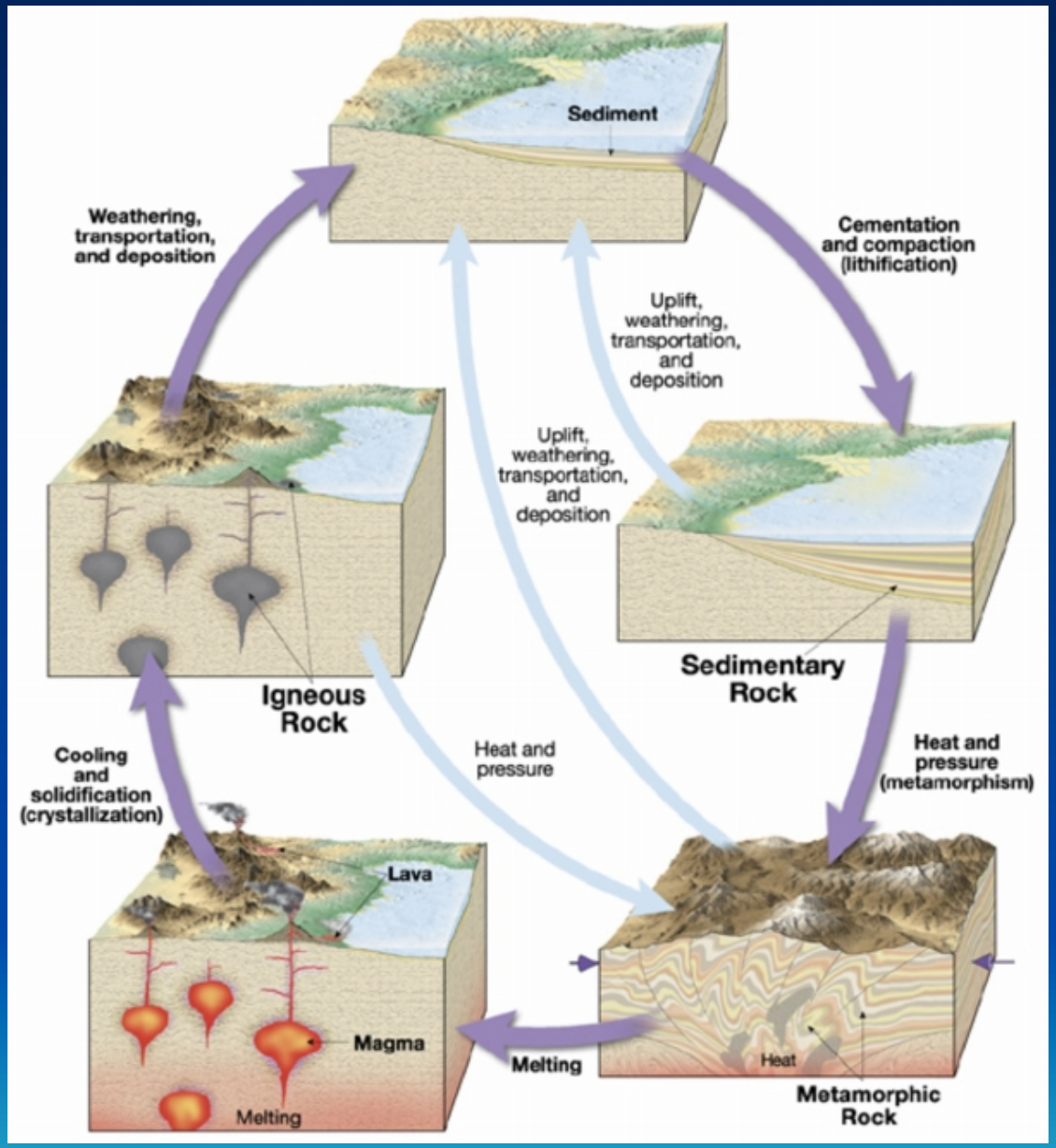
Sedimentary Rocks

Igneous Rocks are weathered and eroded. Sediments are formed. Sediments are pressed and cemented together to form Sedimentary Rocks.

Igneous Rocks

Metamorphic Rocks are melted due to tremendous heat in the mantle. The melted rock forms magma which cools and hardens to form Igneous Rocks.


Igneous Rock
cooling
melting
magma
weathering
and erosion
heat and
pressure
sediments
melting
weathering
and erosion
compaction and
cementation
Metamorphic
Rock
weathering
and erosion
heat and
pressure
Sedimentary
Rock


Sediment
Weathering, transportation, and deposition
Cementation and compaction (lithification)
Uplift, weathering, transportation, and deposition
Uplift, weathering, transportation, and deposition
Igneous Rock
Sedimentary Rock
Cooling and solidification (crystallization)
Heat and pressure
Heat and pressure (metamorphism)
Lava
Magma
Melting
Melting
Heat
Metamorphic Rock